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INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 5 :		(11) International Publication Number:
H01L 41/08	A2	WO 90/16087
		(43) International Publication Date: 27 December 1990 (27.12.90)

(21) International Application Number: PCT/US90/03247

(22) International Filing Date: 7 June 1990 (07.06.90)

(30) Priority data:
363,063 7 June 1989 (07.06.89) US

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(81) Designated States: AT (European patent), BE (European patent), CA, CH (European patent), DE (European patent)*, DK (European patent), ES (European patent), FR (European patent), GB (European patent), IT (European patent), JP, KR, LU (European patent), NL (European patent), SE (European patent).

Published
Without international search report and to be republished upon receipt of that report.

(54) Title: PIEZOELECTRIC DEVICE WITH AIR-FILLED KERF

(57) Abstract

This invention provides a piezoelectric transducer having low density, high compliance and improved piezoelectric properties. These desirable characteristics are achieved by the preparation of a piezoelectric transducer with an air-filled kerf. The piezoelectric elements are held in place by bonding directly to electrodes so that there is no need to embed the elements in a polymeric matrix.

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PIEZOELECTRIC DEVICE WITH AIR-FILLED KERF

Background of the Invention

Field of the Invention

This invention relates generally to piezoelectric materials and more particularly to 1-3 phase connected PZT ceramics for transducer applications and the like.

Description of the Prior Art

U.S. 4,412,148 discloses a PZT-polymer composite fabricated so that an array of parallel PZT strands or rods are embedded in a mechanically compliant matrix of a polymer, such as an epoxy.

U.S. 4,613,784 discloses a PZT glass polymer composite material of 1-2-3 connectivity made from a plurality of generally parallel PZT rods aligned in the direction of a poling electric field secured in the matrix of the polymer with glass fibers aligned both in a direction perpendicular to the PZT rods and in the third orthogonal direction.

U.S. 4,683,396 discloses an ultrasonic transducer having a piezoelectric composite in which a number of piezoelectric ceramic poles are arranged in a plate-like polymer matrix perpendicular to the plate surface in which the volume ratio of the piezoelectric poles is in a range of 0.15 to 0.75 and the height of

each pole is larger than the spacing between adjacent poles.

U.S. 4,726,099 discloses a ceramic polymer matrix composition for use in piezoelectric composites in which the piezoelectric ceramic is a fibrous-like material.

U.S. 4,728,845 discloses a piezoelectric composite of 1-3-0 connectivity having a void within the polymer matrix.

It is generally the objective of the foregoing art to provide piezoelectric materials with flexible low density construction which could be used in the construction of flexible transducers and hydrophones. The attainment of low density and high compliance is one which has not yet been adequately addressed by the developments of the art.

Summary of the Invention

This invention provides a piezoelectric transducer having low density, high compliance and improved piezoelectric properties. These desirable characteristics are achieved by the preparation of a piezoelectric transducer with an air-filled kerf. The piezoelectric elements are held in place by bonding directly to the electrodes so that there is no need to embed the elements in a polymeric matrix.

Brief Description of the Drawing

Fig. 1 is a side view of a representative piezoelectric structure of this invention, with the upper surface partially removed.

Detailed Description of the Invention

Practically all piezoelectric composite materials used for making thickness mode transducers have a 1-3 connectivity structure with posts which are narrow with respect to their height. These posts are made from a piezoelectric ceramic such as lead zirconate titanate (PZT) or lead titanate, although this invention is not limited by the type of piezoelectric ceramic.

The art suggests that these composites perform as superior piezoelectric materials because a polymer is bonded to the sides of the ceramic posts. The polymer is considerably less dense and more compliant than the ceramic. When sound waves strike the composite, the polymer is more easily displaced than the ceramic. Since the materials are bonded together, and the spacing is short with respect to the acoustic wavelength, the limitation on the compression of the filler is the ceramic post. Thus, the energy is

transmitted into the post where it can be converted to electrical energy and removed as a signal via the electrodes. The art is replete with examples of attempts to modify the composition and structure of the ceramic polymeric matrix in attempts to overcome the above-mentioned problems. Representative examples of such attempts are those disclosed in U.S. 4,613,784; 4,412,148; 4,683,396; 4,728,845; 4,628,223; 4,726,099; 4,671,293; 4,640,291; 4,572,981; and 4,518,889. The disclosures of the foregoing patents are incorporated herein by reference.

However, in practice, a transducer is always used in conjunction with additional supporting structures. It therefore is feasible to prepare a piezoelectric transducer without any polymeric filler. In this invention, the filler becomes unnecessary since the forces on the outside layers and electrodes are transmitted directly to the posts.

Referring now to Fig. 1, the piezoelectric transducer 100 of this invention comprises conventional ceramic piezoelectric posts 102 attached at either end to suitable electrodes 104. The electrodes are, in turn, secured to appropriate backing structures 106, such as alumina, epoxy or others well-known to the art. Usually the sides of the transducer will be sealed with a suitable sealing structure such an O-ring or a polymeric layer (not shown). This new construction is referred to herein as an air kerf composite since the posts are separated from each other only by air. As used herein, the term "kerf" refers to the space between the ceramic posts.

One advantage associated with the air kerf composite is that post-to-post isolation will be a function of the surface waves on the front and rear surfaces, as opposed to waves traveling through the filler material. This will lead to better suppression of lateral modes depending on the selection of the layer materials.

The air kerf composite shows an absence of shear resonance, full pressure transfer to the ceramic, zero lateral clamping (which is important at over 60% volume fill) and vastly reduced lateral coupling, as opposed to the polymeric ceramic piezoelectrics.

Any suitable electrodes may be employed in the preparation of the air kerf composite of this invention, such as gold, silver, or nickel electrodes. In addition, the ceramic posts may be made of any suitable piezoelectric ceramic material, preferably PZT. The posts may be in the form of rods, bars, or the like.

One method of preparation of the air kerf composite is to: 1) dice a ceramic as is known in the art for preparation of a normal 3-1 composite; 2) fill the kerf with a substrate which can be either melted, chemically dissolved or otherwise removed; 3) lap the filled composite to thickness; 4) prepare the front and

back layers and sputter electrodes onto them; 5) bond the layers to the filled composite; 6) remove the filler; and 7) seal the sides of the composite as desired.

Other embodiments and modifications of the present invention will be apparent to those skilled in the art upon review of the current invention. Therefore, it is understood that the present invention is not limited by the teachings herein presented and that further embodiments and modifications not specifically delineated herein are included within the scope of the claims.

I Claim:

1. A piezoelectric transducer comprising:

a plurality of piezoelectric posts separated from each other by an air-filled kerf;

electrodes bonded to both ends of said posts;

suitable backing and transfer structures bonded to said electrodes; and

means for sealing the sides of said transducer.

2. An ultrasonic transducer comprising a plurality of ceramic piezoelectric posts bonded to opposing electrodes, said piezoelectric posts surrounded by an air-filled space, said posts arranged

such that their height is perpendicular to said opposing electrodes, the volume ratio of said piezoelectric posts to that of the entire space in the range of 0.05 to 0.95.

3. A piezoelectric transducer of claim 1 wherein said piezoelectric posts are selected from the group consisting of lead zirconate titanate, lead titanate and lead metaniobate posts.

4. An air-filled piezoelectric transducer having posts directly attached to opposing electrodes, said posts separated from each other by air.

5. A transducer of claim 1 wherein said transfer structures are front and rear structures and said front structure has a concave shape.

6. A transducer of claim 1 in which the electrodes are selected from gold, silver and nickel electrodes.

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FIG. 1